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WATER RESOURCES ACTIVITIES
IN THE
UNITED STATES

WATER QUALITY MANAGEMENT

SELECT COMMITTEE ON NATIONAL WATER RESOURCES
UNITED STATES SENATE

PURSUANT TO

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EIGHTY-SIXTH CONGRESS

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SELECT COMMITTEE ON NATIONAL WATER RESOURCES

(Pursuant to S. Res. 48, 86th Cong.)

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STATEMENT BY THE CHAIRMAN

FEBRUARY 26, 1960.

To the Members of the Senate Select Committee on National Water Resources:

As a part of our studies under Senate Resolution 48 of the extent and character of water resources activities that can be expected to be required to provide the quantity and quality of water needed for use by our population and industry between the present time and 1980, I asked the Department of Health, Education, and Welfare to study and report to the committee on needs in the fields of municipal water use and the use of water for pollution abatement. As the studies by the Public Health Service progressed it became increasingly evident that with the magnitude of the demands which are being made on our streams, which will increase greatly in the years ahead, it would be difficult to separate the problems as I had suggested. Problems of securing abundant supplies of fresh water for municipalities are inextricably interwoven with the pollution abatement problems stemming from the use of the same waters to flush away the wastes of our cities.

Accordingly, in making its studies for the committee, the Public Health Service prepared a single report in three parts on the subject of water quality management. Part I, containing projections of future water requirements for municipal use has been printed as Committee Print No. 7; part II, containing projections of needs for pollution abatement has been printed as Committee Print No. 9. The third part continues, on the basis of the material developed in parts I and II, with the development of the subject of water quality management which the Public Health Service believes is the key to the solution of the water resources problems of our cities in the future.

The report discusses water quality and quantity requirements for various purposes, the limitations of streams as waste carriers, the economics of water pollution, and many other aspects of the problems involved in the preparation of comprehensive water pollution control plans. It points out that growing demands for water and limitations on developable supplies mean that we must reuse river flows over and over again in many areas and that we are rapidly running out of clean water. Thus the management of water resources presents a problem of the first magnitude. It concludes with a discussion of research needs and other requirements for water quality management.

This timely report will be of interest to you, to other Members of the Senate, and to all who are interested in finding solutions to the future water problems of our cities and industries and, therefore, I am having it printed as one of our series of committee prints dealing with all aspects of water resources activities in the United States.

ROB'T S. KERR,
Chairman, Select Committee on
National Water Resources.

COMMUNICATIONS

JUNE 24, 1959.

Hon. ARTHUR S. FLEMMING,
Secretary of Health, Education, and Welfare,
Department of Health, Education, and Welfare,
Washington, D.C.
(Attention of Leroy E. Burney, Surgeon General, Public Health Service):

MY DEAR MR. SECRETARY: Reference is made to my letter of June 15, 1959, concerning the work of the Select Committee on National Water Resources. Among the other facets of the committee's work on which an early start must be made is preparation of materials relating to municipal water use and to the use of water for pollution abatement. Among the Federal agencies working in the water field the committee believes that the Public Health Service has unique qualifications for dealing with these matters. Accordingly, it is requested that reports on these two subjects be prepared for this committee by the Public Health Service.

The first of these reports should give us information relating to water use and related matters along the following lines:

1. Per capita water use for domestic, commercial (to include industrial service normally supplied through municipal water systems), and municipal public purposes. We would like to have information on 1959 or another recent year, some information on past trends, and projections on use in 1970, 1980, and 2000. We would like to have this information broken down by State with specific consideration given to major metropolitan areas, in particular Albuquerque, Boston, Chicago, Dallas-Fort Worth, Houston, Kansas City, Los Angeles, New York, Philadelphia, Phoenix, San Francisco, and Washington, as well as any other municipality having unusual problems.

2. Discussion of expected changes in rate of water use giving components of the changes.

3. Relation of cost to use of water and any other information which will throw light on supply-demand relationships for water.

4. Description of major problems in municipal water supply which may be anticipated from projected water use trends covering particularly municipalities or metropolitan areas having unusual problems.

5. Discussion of most efficient municipal water service and use at minimum levels of water consumption.

6. Any other matters in the field of municipal water use in relation to other uses of water which the Public Health Service believes should be brought to the attention of the committee.

The second report should give us information on present pollution hazards and projections of future pollution hazards, generally as follows:

1. Estimated extent of water pollution from industrial water use by type, source, and stream, at present and in 1970 and 1980, with an appraisal of recent effects on water quality by major industrial classification and type of effects. Trends should be discussed and specific examples should be cited. For this category we are concerned primarily with pollution of an inorganic character.

2. Extent of stream and underground water pollution by organic material from municipal sewage and other sources at present and in 1970 and 1980, considering population increases, sewage treatment trends, and other pertinent factors.

3. An estimate of the present extent of avoidable sediment load originating on land with a disturbed vegetative cover, by stream, with comments on the relationship of this type of pollution to other pollution hazards.

4. An appraisal of the extent to which streams should function as waste carriers by 1980.

5. Estimated requirements for water pollution control measures to 1970 and 1980, with recommended measures.

6. Any other matters in this field which the Public Health Service believes should be brought to the attention of the committee.

We would like this information to be made available in the form of two reports of not more than 10,000 words each, with whatever tables, charts, appendixes, and graphic illustrations as may be considered necessary. It would be most helpful if this information could be furnished the committee by October 1, 1959.

The committee staff will be happy to discuss any problems that may arise in the preparation of this material with representatives of the Public Health Service.

Sincerely yours,

ROB'T. S. KERR,
Chairman.

DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE,
PUBLIC HEALTH SERVICE,
Washington, D.C., February 16, 1960.

Hon. ROBERT S. KERR,
Chairman, Select Committee on National Water Resources,
U.S. Senate, Washington, D.C.

DEAR SENATOR KERR: In accordance with your request of June 24, 1959, a report in three parts dealing with "Present and Future Municipal Water Supplies and Water Pollution Problems" has been prepared and enclosed herewith for the use of the Senate Select Committee on National Water Resources.

We have not separated the subjects of water supply and waterborne wastes, since we find that they must be dealt with as parts of one problem in both the quantitative and qualitative sense. The enclosed report has been developed with this concept in mind. For convenience in using the information contained therein, however, the report has been prepared in three parts:

Part I. Present and future municipal water requirements.

Part II. Present and future pollution loads and problems.

Part III. Water quality management.

We appreciate this opportunity to be of service to you and the select committee. If additional information is required, we will be pleased to assist you.

Sincerely yours,

ARNOLD B. KURLANDER,
Acting Surgeon General.

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WATER QUALITY MANAGEMENT

PART III OF THE REPORT OF THE PUBLIC HEALTH SERVICE, OF THE DEPARTMENT OF HEALTH, EDUCATION AND WELFARE, ON FUTURE MUNICIPAL WATER SUPPLY AND WATER POLLUTION CONTROL REQUIREMENTS IN THE CONTINENTAL UNITED STATES, TO THE SENATE SELECT COMMITTEE ON WATER RESOURCES

INTRODUCTION

Part I of our report pointed out that by 1980 total withdrawals of water for all purposes, from surface and underground sources in the United States, might almost equal the 650 billion gallons per day of total developable supplies and that by year 2000, such withdrawals could amount to almost twice the total supply. For municipal purposes alone, demands in year 2000 could equal five times present requirements, or about 85 to 90 billion gallons per day. As pointed out, however, such huge demands are not necessarily a cause for alarm, since water can be used over and over again as it flows to the sea. The mere adding up of all uses is, therefore, not a valid measure of the amount of water that must be supplied.

The alarming thing about this situation is not the total amount of water required, but the fact that water, in the process of being used, becomes polluted, and may be rendered unfit for further use for some purposes, unless means can be found to cleanse it. This situation is further complicated by past preferences based on public health considerations and by the popular feeling that water once soiled must be thrown away; present municipal water supply practices are, wherever possible, based on this point of view. There is, of course, usually no more logical reason for throwing away dirty water than for throwing away a dirty shirt. Both dirty shirts and dirty water can be laundered and reused. For both shirts and water, however, it is essential that those substances which cannot be removed by cleaning, such as stains or certain persistent chemicals, be kept away from them in the first place.

Fishing and water-oriented recreational pursuits also require relatively clean streams and lakes, and demands for these facilities will increase greatly as population continues to expand and living standards and leisure time increase. However, because streams and lakes must, for the foreseeable future, at least, continue to function as residual waste carriers, the management of water resources presents a problem of the first magnitude, because we are rapidly running out of clean water. Adequate treatment of wastes before discharge into water courses is becoming imperative.

Part II of our report presented data and information on the amounts and kinds of pollutants affecting our fresh water resources. In addition to ordinary sewage and related organic substances, which deplete the dissolved oxygen in water as they decompose, there are numerous other substances of a chemical, biological, bacteriological, or organic nature which also affect water use or may be detrimental to health. These include: (1) infectious agents, (2) chemicals which act as aquatic plant nutrients, (3) various new organic chemical exotics such as detergents and insecticides, (4) a wide array of other mineral and chemical substances, mostly produced through industrial processes, (5) sediments from land erosion, and (6) radioactive substances. In addition, the heat added to water when it is used for industrial and powerplant cooling has an adverse effect upon aquatic life and also has the effect of adding additional oxygen demanding pollution to water, because it reduces the amount of dissolved oxygen contained in the water. Thermal stratification also reduces the oxygen in water taken from the lower levels of reservoirs.

All these pollutants are increasing at a rapid rate as increasing population and industrial expansion place heavier demands upon our water resources.

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Some pollutants are infectious or highly toxic, both to animal and human life. Others, while less toxic may have long-term cumulative effects. The effects of still other substances are as yet not clearly understood. Many new substances are added every year, the effects of which simply are not known. Some pollutants have detrimental effects on industrial processes of succeeding downstream water users, or interfere with water purification processes. The visible effects of pollution also reduce or eliminate esthetic values.

Although processes for removing oxygen demanding organic wastes, settleable solids and disease-producing organisms from sewage still require substantial improvement, they have reached a relatively high degree of efficiency, but practical processes for the treatment or removal of many polluting substances in solution have not yet been developed.

Part II concluded that, because of the limited supply available, it would be necessary to reuse water many times over if our total future demands for water are to be met. In order to do this, it will be necessary to provide for the control of water quality as well as quantity. "Water Quality Management" is the subject of this part of our report.

NEED FOR WATER QUALITY MANAGEMENT

Past water conservation and development projects were concerned almost entirely with water volumes. Dams and related structures were constructed to store water for power, irrigation and flood control, and aqueducts and diversion structures were constructed to transport water from areas of surplus to areas of need. Such projects, which have done much to increase the volume of available water, will continue to be needed for the provision of water to the limit of our economically capturable and transportable water resources.

Because the Nation will presently reach the limits of its capturable supplies, while water demands are increasing sharply with no letup in sight, however, it becomes abundantly clear that for the foreseeable future, water needs can only be met by using the available supply over and over again. This has already happened in some of the more heavily populated and industrialized areas of the country. Thus, during periods of low flows it has been estimated that the water of the Ohio River is reused almost four times before it reaches the Mississippi. In the future, the waters of many of our major rivers may have to be reused many more times than this.

To be reusable, water must be of the right quality. Used water is almost always polluted and pollution degrades the physical, chemical, biological, bacterial, and esthetic qualities of water, the degree depending upon the kinds and amounts of pollution in relation to the extent and kind of reuse. Pollution can be just as effective in reducing or eliminating a water resource as a drought or consumptive withdrawal.

Because of the rapid increase in the kinds and amounts of pollution occurring in water, water quality management must now be given the highest priority, if we are to meet future water requirements. An important segment of water quality management has been and will continue to be accomplished by storage of good quality water for water supply purposes and for further dilution of treated wastes. Municipalities and industries will reach farther and farther to tap additional water sources not yet affected by pollution, and such water supply projects will become larger and larger.

For the Nation as a whole, however, water quality management can best be effected by the prevention and control of water pollution. As increasing demands are placed upon limited supplies, more usable water can be provided to meet these needs by controlling pollution than by any other means.

PROBLEMS OF WATER QUALITY MANAGEMENT

Stated in simple terms, water quality management means providing the right quality of water in the right quantities for the purposes to be served at the points where it is needed. We have been caught unaware, however, by the huge demands for water resulting from rapid population and economic growth, and are relatively unprepared sociologically, economically, legally, or technically to handle them. We have oversold the cheapness and plentifulness of water and failed to emphasize the necessity and value of pollution control. We are attempting to manage the new, complex problems of today with tools that were designed for the problems of yesterday.

If water of satisfactory quality and adequate quantity for future requirements is to be provided,

answers must be found to a number of questions, including the following: (1) What are the actual water quality requirements for the various water uses? (2) To what extent should the Nation's streams function as waste carriers? (3) What are the valid economic factors in managing water quality? (4) What water quality priorities are needed to resolve the differences between the conflicting and competing water uses, and how shall they be established? (5) Who gets water of what quality, how much does he get, and how much can he be reasonably expected to pay for it? (6) Who should manage water quality and how? (7) How long will our present waste treatment processes, primarily aimed at treating municipal sewage only, continue to provide sufficient water quality protection? (8) What are the solid facts regarding the present effects of pollution on water quality, and what are future trends? (9) How do we muster the support required for effective management of water quality?

Finding the answers to these questions will not be easy, and is not the purpose of this document. Water quality management is both a concern and a responsibility of every segment of our society, political, social and economic, and calls for the exercise of sound judgment and discerning statesmanship. For satisfactory decisions, however, much factual information regarding water availability, quality, use and control, including the various water pollutants and their effects, must be collected, analyzed, and disseminated, and sound technical, legal, and administrative procedures for the cooperative planning for, and the multiple use of, our water resources must be developed and applied. The following sections discuss these requirements as a basis for achieving sound water quality management.

WATER QUANTITY AND QUALITY REQUIREMENTS FOR VARIOUS PURPOSES

In order to better understand what is involved in water quality management, it is essential to understand the water quantity and quality requirements for the various purposes which water serves. These purposes include municipal water supply, recreation, industrial water supply, irrigation, industrial, power and space cooling, fish and wildlife preservation and propagation, and navigation.

Municipal water supply.—Because of the anticipated tremendous population increase in the next four decades, and the fact that by that time most people in the United States will be living in metropolitan areas, we may, by the year 2000 require as much as 85 to 90 billion gallons of water per day for municipal purposes. This is five times present requirements. Most of this water must come from rivers and lakes which must also serve other purposes. Very little of this municipal water will actually be permanently removed from the streams of the country. Most of it will, after use for household, commercial, and industrial or public cleaning and waste disposal purposes, or for industrial processing, be returned to the rivers or lakes, generally with various polluting substances added. Some of this water will, however, be used for watering gardens, lawns, and public parks, and much of this will not return to the watercourses.

Cities usually have only a single system of pipes for water distribution. Provision of dual supply systems would, of course, permit use of less highly treated water for most general purposes, with highly treated water restricted to consumptive uses such as drinking and cooking. Public health officials have always strongly objected to such dual systems, with their inherent danger to the public health which would result from cross connections or misuse. Consequently, all municipally supplied water must be of drinking water quality. This means, therefore, that the water source itself must be of such quality that after treatment, the water will be both safe and acceptable in taste and appearance for human consumption. Since too many of the polluting substances now reaching public water supply sources are not removable by existing economical treatment methods, greatly intensified programs for the careful control of pollution are required to insure preservation or improvement in the quality of water sources serving municipal systems.

Industrial water supply.—The growth of industry in the United States in recent decades has been phenomenal and this growth is expected to continue into the foreseeable future. Industry will require 80 percent and more of the expected increase in total future water requirements and will account for 65 percent or more of all fresh water used in 1980 and 2000. This is not only because of rapidly rising production but because many new industrial processes need more water than the old ones.

There are few communities today that do not have at least one industrial plant and are seeking more. The location of industry is guided by many considerations, but among them a satisfactory water supply is important. Water-using industries are now racing to locate at the dwindling number of sites along out major water bodies, particularly the Great Lakes, the Ohio River, and the lower Mississippi, where large volumes of satisfactory water can still be secured without excessive expense for treatment. Other industries are moving into the Southwest and other water-short regions where advantages other than water availability are overriding, but where water must, nevertheless, be provided, often by diverting it from irrigation use.

Large quantities of water are withdrawn for industrial use directly from rivers, lakes, and ground-water aquifers. Much of this water is used for cooling, and must at least be of suitable temperature for this purpose. While it need not meet potability standards, it must also be free of corrosive chemicals or those which would leave scale or other heavy deposits in the cooling apparatus. It should also be sufficiently free of organic compounds and aquatic life to require only simple chlorination to prevent growth of slimes and algae in the cooling equipment.

Substantial amounts of water are used directly in industry processing. This water must be of such quality that it will not have detrimental effects on the final products. These uses range from food processing, requiring water treated to potability standards, to pulp and paper mills and complex chemical plants, requiring varying degrees of purity and cleanliness. Many of the substances now reaching our water sources can be harmful to some industrial products and water supplies suitable for industrial purposes are becoming harder to find.

Water for irrigation.—Irrigation will require the next largest segment of increased water needs, after industrial requirements, and will account for about 28 percent of total fresh water use in 1980 and 2000. A continuance of the trend toward supplemental irrigation in the East would drastically increase these figures and have far-reaching effects on other water uses, both with respect to quantity and quality.

Principal quality problems affecting use of water for agriculture are those resulting from excess quantities of detrimental chemicals such as common salt and alkalis. Boron, derived from washing compounds, is also toxic to plants, even in very low concentrations. In some Western States, programs for the control of salt and alkaline substances are required. Control of chemicals such as insecticides and herbicides, which may get into water intended for irrigation use is also important. In certain local areas where sewage effluents could become an important source of agricultural water, better control of infectious agents in these effluents would also be required, particularly where the crops grown are intended to be consumed raw.

Use of water for irrigation is largely a consumptive use, which means that a substantial part of the water so used is evaporated, or transpired, and is no longer available for other uses further downstream. What is returned to watercourses is often laden with salts, insecticides and other chemicals.

Water requirements for fish and wildlife and recreational purposes.—Both fish and wildlife preservation and propagation and recreation are nonwithdrawal uses of water of emerging significance. Both activities require high-quality water, paralleling that for public water supplies. The demand for clean water for swimming, boating, sport fishing, water skiing, and other water-related sports has grown tremendously in recent years and will continue to do so. In a number of States the recreation and sport fishing industries are the largest source of income and in a growing number of other States, are an important source of income.

There were in 1947 a total of 1,857,000 outboard motors and 2,440,000 pleasure boats in use on our rivers, lakes, and coastal waters. By 1957 these figures had grown to 5,190,000 and 7,071,000, respectively. The sale of boats in this country is growing at a more rapid rate than was ever achieved in the sale of automobiles. In 1955, a total of $1,425 million was spent on fresh water fishing alone and 17,700,000 fishing licenses were taken out. Water-oriented recreation and sport fishing together add up to an important segment of total national economic activity contributing importantly to total income.

If, as predicted, the number of working hours and the length of the workweek continue to decrease with improved business and industrial techniques, personal income and living standards will continue to improve, and more and more Americans will have both more leisure time and

more income with which to enjoy outdoor recreational pursuits. Since, in addition to fishing, a very substantial part of outdoor recreation is water oriented, these activities will require substantial increases in the amounts of clean, esthetically attractive streams, lakes, and coastal areas dedicated to these purposes.

Water quality requirements for sport fishing and for recreation are of the highest order. Sport fish require water which contains at least five parts per million of dissolved oxygen. Chemical substances such as some insecticides and certain other chemicals are definitely toxic to fish and must be kept below critical concentrations. Polluted water is unattractive for boating, water skiing, swimming, or even picnicking, and is also a health hazard in connection with such uses. The polluting of waters which are used for fishing or recreation may thus result in the total destruction of these water bodies for these purposes. The problem is not only economic but carries esthetic and social implications as well.

One other increasingly important aspect of pollution in recreational waters stems from the recreational use itself. As more and more pleasure boats are used, the waste discharges from them constitute a source of pollution which is becoming increasingly serious, and which requires regulation or control.

Recreation and fishing are water uses which compete with other uses for the same water. Suitable flow regulation, together with adequate abatement or control of pollution, is therefore required as part of a comprehensive water quality management program having as its objective the equitable use of water for all purposes.

Navigation requirements.—Except for a possible health hazard to the personnel involved, water pollution normally has little effect upon navigation facilities and operations. There is, however, a direct relationship between navigation requirements on a river and water quality management for pollution control purposes. Where the run of the stream is insufficient, navigation on inland rivers is achieved either by releasing stored water at times of low flow, in order to maintain the proper depth of water in the channel, or by constructing a series of dams and locks in a river to provide slack-water navigation. Where navigation is provided by the first method, the river will often also provide a considerable volume of water for the dilution or transportation of treated wastes. Where navigation is achieved by means of a series of low dams and locks, the actual flow of the river may be quite low during dry-weather periods. In the latter case, the transportation of wastes and their dilution will be adversely affected. These possible situations must be considered in preparing comprehensive plans for water quality management of a river basin.

Some forms of pollution, such as acids or acid-forming wastes, also have a direct effect upon navigation equipment as, for example, the corrosion of concrete structures and steel hulls and lock gates. Other wastes may foul the bottoms of boats or clog their cooling systems. Accumulations of sludge and silt deposits also clog navigation channels, as in the case of the Chicago Drainage Canal. Where waterway traffic is heavy, wastes from the boats can also become a problem. Where the waters traversed are also the sources of water supply for the vessels themelves, pollution can be a source of danger to the vessels' occupants.

THE LIMITATIONS OF STREAMS AS WASTE CARRIERS

Through the years, a basic concept in the design of sewage and industrial waste treatment works has been to take full advantage of the selfpurifying capacities of streams by discharging wastes into them. The degree of treatment provided was tailored to the diluting capacity of the stream and to its oxygen resources, and the stream was often called on to do much or most of the job of treatment. We were dealing then, of course, with wastes largely amenable to biological stabilization and of known behavior. Within the limits of the flexibility of available processes, treatment was provided sufficient to prevent nuisance conditions, maintain fish and aquatic life, and to protect downstream water supplies.

Now, we are in a period of rapid population and industrial growth that is expected to continue. Municipal and industrial waste outlets are becoming more numerous and are carrying much greater volumes of stronger wastes of growing complexity. Merging cities bring sewer outlets closer to water supply intakes. The task of collecting, treating, and disposing of municipal wastes alone is already taxing the administrative and financial resources of our public agencies. Furthermore, the diluting capacity and oxygen resources in the

streams are no longer adequate for assimilating waste effluents in a growing number of places. The problem presented by tomorrow's supercities is even more staggering to contemplate. Troublesome conditions are already being encountered below a growing number of large cities because of increased flows and stronger wastes, even though the best treatment methods available are being applied. Chicago, Indianapolis, Columbus, and Dayton are only a few of the examples in the Midwest. Waste water from other cities located on coastal waters such as Los Angeles, San Francisco, and New York, are also creating problems.

These situations are certain to multiply rapidly in the future and the conditions will get worse unless we are able to collect and treat such wastes more efficiently and economically than is now possible. At the same time that streams are receiving more and more pollution, they are also being called on to supply ever-increasing volumes of water of suitable quality for all purposes. For the foreseeable future, at least, streams and lakes must continue to function as the final place of disposal for waterborne wastes, simply because there is nowhere else to put them. From this point on, however, we must undertake to engineer the wastes out of the streams to the maximum extent possible so that their waters can be used over and over again for all of the purposes which water must serve. We can no longer wait until a serious pollution situation arises which threatens, or in fact destroys, needed waters, before action is taken.

ECONOMICS OF WATER POLLUTION

Almost everyone agrees that the Nation and its communities, as well as business and other private operations and individuals, incur losses or damages because of water pollution. Some of these losses or damages are reflected directly in additional costs which must be met, such as the payments for the construction, operation, and maintenance of water treatment facilities. By far the larger share of the total damages is not directly accounted for at all, however. The impairment to health, the loss or diminution of fishing and recreational uses, and depreciated property values, all caused by polluted waters, have an adverse economic impact which is diffused throughout society. This is paid for through the reduction in utility of the water resource and the restriction on economic growth rather than through dollar payments for corrective devices. Unfortunately, these indirect consequences of pollution are not readily expressed in dollar terms because of their diffusiveness and because they are not recorded by direct, open market transactions. Nevertheless, such adverse consequences are real and constitute a handicap to the fulfillment of economic and social goals.

Pollution control measures alleviate these adverse conditions and produce economic benefits associated with the improved waters. These benefits are often not apparent to the public, however, because they constitute insurance for future usefulness as well as for immediate purposes, or may be indirect or intangible. The computation of these benefits faces the same difficulties as the computation of the total damages. That is, the dollar measurement problem has not yet been solved and a yardstick for actions or events not recorded in market transactions is lacking. Many of the benefits from pollution control are in this nonmarket realm, i.e., enhancement of fishing and recreational opportunity, protection to health, scenic improvement, and assurance of the future utility of water resources for various other purposes. The private market price system, therefore, cannot be relied upon solely or chiefly to provide the measurement. New devices for taking into account the social or public values will need to be invented. These devices should enable definite answers to be obtained for such important questions as:

1. What does water pollution cost a community, a region, or the Nation in damages for all consequences?
2. What are the specific benefits from alleviation of these damages and what is their economic worth?
3. Who will benefit from the controlled pollution and to what extent?
4. How much can be justifiably spent in controlling a pollution situation?
5. How should the costs of control be apportioned among the members of the community, the region and the Nation?

Obviously, answers to these questions are essential for sound economic planning of water resources programs. Still, the objectives will not be attained just because these measurement

obstacles are overcome. A major hindrance to achievement is the apparent reluctance of the public to finance programs for pollution control. Much of this reluctance is attributable to the lack of identification between tax payments and pollution control services or functions provided by government. Much of the expenditures for pollution control are paid for through general taxation, but the taxpayer frequently does not see a direct connection between these taxes and the benefits resulting from cleaner water. The lump-sum nature of payments made to the government for public facilities and services, which are as essential to well-being as are those obtained from the private realm by direct purchases, results in the situation that these services suffer by comparison with privately furnished services which are paid for separately and directly. There is thus a need to improve considerably the public understanding of governmental expenditures so that the public will have an appreciation of the nature of, and necessity for, the services being bought. Pollution control, as well as other prógrams, will then be in a much improved position to protect and further the public interest.

The application of basic economics is needed to develop valid yardsticks by which reliable dollar measurements can be made of the costs of water pollution and of the benefits from its control. With such data, water resources management can be accomplished on a sounder economic basis. Achievement of this goal will require measurements for the value of each water use. These may well differ according to the region or situation involved.

COMPREHENSIVE PROGRAMS FOR WATER QUALITY MANAGEMENT

The need for comprehensive programs.—Effective water quality management requires preparation of comprehensive pollution control programs. This was recognized by the Congress in section 2 of the Federal Water Pollution Control Act, Public Law 660, 84th Congress, which states that—

> The Surgeon General, after careful investigation, and in cooperation with other Federal agencies, with State water pollution control agencies and interstate agencies, and with the municipalities and industries involved, shall prepare or develop comprehensive programs for eliminating or reducing the pollution of interstate waters and tributaries thereof and improving the sanitary condition of surface and underground waters. In the development of such comprehensive programs due regard shall be given to the improvements which are necessary to conserve such waters for public water supplies, propagation of fish and aquatic life and wildlife, recreational purposes, and agricultural, industrial, and other legitimate uses.

For nearly 30 years the Nation has been moving toward basinwide and regional water resources planning. The first efforts were those of the National Resources Planning Board during the 1930's. The latest efforts are those of the U.S. study commissions in Texas and in the Southeastern States, created by the Congress in 1958 to undertake studies for the full development for all purposes of the water resources in these two regions.

In between the National Resources Planning Board and the two newly established study commissions, other multiple-purpose planning programs have been undertaken, such as the Tennessee Valley Authority program, the Coulee Basin program (Washington) and the Central Valley project (California) in the middle and late 1930's; the Missouri Basin development plan (Pick-Sloan plan) authorized in the 1944 Flood Control Act; and the Federal interagency river basin planning studies of the New England-New York Inter-Agency Committee and the Arkansas-White and Red River Inter-Agency Committee in the early 1950's.

Most of these earlier programs and studies for water resources development emphasized the quantitative control of water. Since water is becoming limited, however, it is essential that attention be given to the problem of maintaining water quality as well as quantity in river basin planning. This is especially important because the economic resources which can be allocated to development and utilization of water are not limitless, and efficiency and economy, as well as equity and fairness, require that the development and use of the waters of a river basin be planned on a comprehensive basis. Pollution control programs based on an understanding of the quality of water required for all purposes must be an integral part of such comprehensive planning.

Procedures involved.—In preparing a comprehensive water pollution control plan for a river basin, it is necessary to ascertain the present and future water requirements for each urban and

industrial center, each farming and irrigation area, each power development, each fishing or recreational area, for navigation, and for all other water uses. The water quality requirements for each such use must also be determined, as well as the existing quality of the available waters. The municipal and industrial waste loads to be provided for at each point on the river, together with the degree of waste treatment required to maintain needed river water quality at each point, must be estimated. The total feasible storage capacity which must be provided in order to maintain at all points in the river the necessary water quantity and quality must be computed. All of these factors must then be correlated to determine optimum possible use of the river.

This is not an easy task. There is a level of industrial and population growth which any watershed can support, and still maintain a quality of water which will satisfactorily serve the industries and the population with water for drinking, processing, cooling, bathing, fishing, irrigation, and all other legitimate purposes. In some river basins there may not be enough water available for every desired use or purpose, and choices must be made. Under these circumstances, it may be desirable or even necessary to prepare plans for alternative possible combinations of basin development as a guide in allocating water to various purposes.

The preparation of such basin development plans is a procedure in which, starting in the headwaters and working downstream, various assumptions as to possible uses, withdrawals, and discharges are used as the basis for working out possible combinations of development. At every stage in this procedure, water quality plays an important part, and the determination of possible pollution loads and of facilities needed for their abatement and control are an essential part of the overall plan. Because both the nature of wastes and the methods of treating them is expected to change radically in the future, however, these plans must remain flexible and susceptible of continual modification as changes warrant. The plan, itself, should, nevertheless, be in sufficient detail to guide future development.

State water pollution control agencies, State and Federal construction agencies, research institutes, banking, industrial, legislative, and other interests should all participate in the preparation of pollution control programs.

Magnitude of the program.—It is estimated that the preparation of a plan for a comprehensive pollution control program for a moderate-size river basin area would take about 3 or 4 years and might cost somewhere between $1 and $3 million. A nationwide program of such studies, looking toward the ultimate long-range water quality management of all rivers for optimum use, might well require continuing expenditures of perhaps $8 million or more per year, for many years. In view of the increasing demands upon our definitely limited water resources, such a program of planning studies is essential to the continued well-being of the country.

INFORMATION NEEDED FOR WATER QUALITY MANAGEMENT

General statement.—Successful management of water resources requires adequate information. As pointed out in part II of this report, there are instances where we even lack the necessary information as to the sources of some of the wastes entering our streams and lakes, or their strength, volume, or characteristics, or exactly what happens to them after they reach the river. The effects upon human and animal life of some of the new pollutants are unknown, or only suspected. How to economically remove or otherwise control many of the substances polluting water presents a set of complex problems for which answers are also badly needed.

Both the collection of data and the application of research to the solution of water pollution problems need to be greatly expanded. In addition, the behavior of the streams, lakes and estuaries themselves, in diluting, transporting, and purifying wastes in general needs to be better understood. For example, our knowledge and experience on lateral and longitudinal mixing and dispersion of wastes in streams should be expanded. Plumes of waste may often be traced many miles along a watercourse, and peaks of pollution travel downstream for long distances. Obviously, in such cases the full diluting and self-purifying capabilities of the stream are not being used, and pertinent questions are raised regarding the adequacy of sewer outfall designs. Because it is essential

that our streams be used efficiently, the fluid dynamics of streamflow as applied to waste discharges and assimilation must be better understood.

Another example of inadequate knowledge of behavior is presented in tidal estuaries and large lakes. Twenty-three States depend on estuaries or other coastal waters to remove waste effluents. However, one of the profound and unsolved questions in waste disposal concerns the ultimate fate and effect of a waste discharged into a mass of tidal water, or a large lake subject to variable wind current movements. An acute need exists for the development of techniques for predicting the pattern of water movement and what happens to wastes discharged into such waters. While the feasibility of using models to replace or to supplement field studies appears promising, considerable study is required to determine the extent to which these devices may be employed usefully in the study of pollution in streams and tidal waters.

Basic data requirements.—Basic data for pollution control consist principally of information on the sources, kinds, and amounts of pollution; the causes of pollution and its effects on water quality and uses; the present and future intended uses of waters; the pollution prevention and control measures required to accommodate the planned water uses; the kinds, costs, and efficiencies of remedial treatment works; and the costs and benefits associated with pollution and its control.

These data need to be collected, evaluated, and distributed on a cooperative basis among the water resources agencies concerned. To make the data more reliable they need to be collected on a continuing basis in all the river basins; to make them more usable they need to be made available on a continuing basis. We need to know where and why we are gaining or losing ground in controlling pollution, and to maintain a water intelligence that will detect pollution situations as they arise before they become major problems. We need this surveillance and intelligence both on interstate and intrastate streams.

Basic data collection and evaluation programs still need to be greatly accelerated by all water pollution control agencies, local, State, interstate, and Federal. Until recently few programs of water quality monitoring could present a realistic picture of changing quality conditions in a stream, and those were usually developed at great expense in special problem situations. Progress in securing such data necessarily depends on the availability of effective procedures and programs for sampling and analyzing water quality.

The Public Health Service has established a basic data collection program, the most recent phase of which was started in 1957. This is the national water quality network, which is now operating 62 stations on interstate streams and the Great Lakes in a proposed network of 250 to 300 stations considered necessary to provide minimum interstate water quality coverage. The network is currently being expanded to 75 stations, and an increase to 120 stations is being planned for 1961.

The principal objective of the network is measurement of long-term trends in water quality at key interstate points. Collected samples are examined for coliform bacteria (as an index of bacterial pollution), for aquatic organisms, radioactivity, synthetic organic chemicals and for various other conventional physical and chemical substances. The program provides the means for continuous evaluation of the quality of water resources.

In addition to the national water quality network, inventory data covering physical, operating, and related information on water supply, sewage, and industrial wastes distribution, collection, and treatment facilities are collected by the Public Health Service for the entire United States. This information is generally obtained through and in cooperation with the various State health and water pollution control agencies. While data for municipal and other public facilities is essentially complete, data on industrial wastes is still sparse and sketchy, and needs to be greatly expanded.

The third category of basic data collected deals with levels of construction, unit costs, service charges, financing of facilities, and other economic data, including measurement of damage by pollution and of benefits resulting from pollution control.

The basic data program, as a whole, is designed to assemble, examine, and interpret the facts which enable water pollution control agencies and other concerned to determine the scope and character of problems to be solved. Adequate data will enable these agencies to carry out their

responsibilities in comprehensive planning for water quality control. Much needs yet to be done, however, to extend the coverage of these basic data collecting programs, which should include not only surface water resources but ground water resources as well.

A number of the States also have basic water quality data collection programs underway. If the quality of the Nation's water resources is to be intelligently managed, however, all agencies will need to develop comprehensive, cooperative basic data programs on a continuing basis. Most agencies require increased appropriations before this can be done.

RESEARCH NEEDS

(*a*) *Need for new waste treatment methods.*—Water supply and pollution trends show that one of the most pressing problems in water quality management is the need to develop new treatment processes, which will remove more of the contaminants from municipal wastes than we are able to do by present methods. Present treatment methods now remove only 75 to 90 percent, each, of the suspended solids and the biochemical oxygen demand, called the BOD, in domestic sewage. Little of the total nitrogen and phosphorous is removed; their availability for stream fertilization and algae growth is actually increased. Because of these deficiencies in present treatment methods, large quantities of water must be available to dilute and transport the residual wastes after treatment of sewage, and when it is not available, serious pollution problems result.

Unless new methods of treatment are discovered, the volume, strength and complexity of future municipal wastes can only result in the discharge of larger and larger amounts of impurities into badly needed water resources. As an illustration, Chicago, with modern treatment facilities, pours into the Illinois Waterway waste waters which have pollution effects equivalent to the discharge of sewage from about 1 million persons and contains solids—natural and synthetic, organic and mineral—amounting to about 1,800 tons per day.

The Chicago situation is a classic example of the profound economic, social, technical, and legal difficulties inherent in the growing metropolitan sewage disposal problems already with us and certain to increase in number. Conventional sewage treatment methods of today have not solved the problem, so the courts and the Congress have been petitioned to solve it by providing more diluting water. In the case of Chicago for example, permission has been requested to divert additional water from Lake Michigan into the Chicago Drainage Canal. The ultimate solution for all such cases, however, will require us to increase our knowledge of how to remove much more of the contaminants from metropolitan wastes, particularly those which remain in solution following existing so-called complete treatment. To do this, we must develop new treatment processes, probably based on entirely new concepts and principles, that will achieve what approaches conversion of waste waters to fresh water. This will require a major coordinated research program which must utilize the best minds in the country and be able to attract physicists, physical chemists, hydrologists, economists, and devotees of other disiplines whose skills have not, up to now, been fully utilized in water pollution research.

The Public Health Service has already initiated a limited program of research directed toward achieving greatly improved removals of impurities from municipal wastes. An all-out, well-supported research effort is needed, however.

(*b*) *Other research needs.*—There is almost a complete lack of knowledge of the role of viruses in water pollution because we have not been able to develop techniques for isolating and identifying them in dilute solutions, although we know they are there. Even the fate and importance of pathogenic bacteria in streams are inadequately understood. Our epidemiological and toxicological techniques for measuring and tracing the effects of water pollutants are as yet poorly developed. The effects of the pesticides, insecticides, and detergents are little understood, and their general removal from municipal water sources, if present, is practically impossible with present methods. Not enough is known about the behavior of radioactive wastes in water, or the effects on humans from using water contaminated by such wastes. Many other problems that have been with us for years still remain to be solved. Among these are pollution from land drainage, silt from erosion, acid mine drainage, natural salt deposits, mineralization from irrigation practices, and cumulative concentration of chemicals

in streams caused by repeated reuse of water by municipalities and industries. Following is a partial list of some of the research projects which should be either started or expanded:

1. Methods for detecting, isolating, identifying, and measuring new contaminants, especially those measured in trace or micro quantities (i.e., synthetic organic chemicals, pathogens such as viruses, etc.).
2. Physiological and toxicological effects of new contaminants (both acute and long term) on humans, as well as upon fish and wildlife.
3. Effectiveness of water and waste treatment methods on these new contaminants with development of new methods where necessary.
4. Behavior and fate of various contaminants in the water environment.
5. Overall coordination of related research by Federal, State university, and other laboratories.
6. Orientation of research toward possible utilization of waste products.
7. Development of new means of waste monitoring.
8. Determination of the nature, peculiarities, types, and effects of ground-water pollution, with emphasis on methods of control.
9. Development of economical methods for the ultracleansing of waste waters.
10. Review and improvement of present methods of water quality measurements, such as the BOD—dissolved oxygen relationship.
11. Determination of possible epidemiological effects of pollution.

The backlog of unsolved water pollution problems and the new problems that are developing make it abundantly plain that a major scientific research effort is urgently needed. Research takes time and perhaps time is now more critical than money.

Support for scientific water pollution research has averaged less than $1 million a year from all sources until very recently. Even now research expenditures total less than $6 million of which the Federal Government spends $2.5 million, industry about $2 million, and the remaining $1.5 million is provided by State governments, including university expenditures. This seems an exceedingly small sum when compared to the large backlog of unsolved problems and the rapidly multiplying new ones resulting from new technologies and changing living standards and patterns.

OTHER REQUIREMENTS FOR WATER QUALITY MANAGEMENT

Construction of remedial works.—The only time when construction of sewage treatment facilities kept up with sewer construction in this country was during the Federal public works programs of the 1930's. Before that time, and since, the number of persons served by sewers increased much more rapidly than the number served by sewage treatment facilities. The construction of industrial waste treatment facilities has never kept up with the increase in the number of industrial sewer outlets nor the increase in production of wastes. As a result, a large backlog of needed sewage and industrial waste treatment construction has accumulated through the years.

Nearly 2,900 new sewage treatment works are needed to serve 19.5 million persons living in communities that have never provided treatment for their wastes. Another 1,100 new plants are needed for 3.4 million persons in communities where treatment works built in the past have become overloaded or obsolete. In addition to these 4,000 communities needing new plants, another 1,630 communities have sewage treatment facilities requiring enlargement or the addition of new units or processes to adequately serve populations totaling more than 25 million.

This backlog is not the whole problem, however. Population growth and urbanization create new sewage treatment needs continuously, and existing treatment works become obsolete. If municipalities are to catch up with treatment needs by 1965, they will have to spend $1.9 billion to eliminate the backlog, $1.8 billion to provide for new population growth, and $900 million to replace plants that will become obsolete. This is a total of $4.6 billion and for the period 1958–65 would require municipalities to spend an average of $575 million a year. Since that level was not reached in 1958–59, it will now require expenditures of nearly $600 million a year to catch up with needs by 1965.

Information on industry's waste treatment construction needs are not nearly as complete as those for municipalities. This is one of the serious gaps

in basic data collection that must be filled. However, surveys by the Public Health Service in 1950 and 1954, and information in the 1957 inventory indicate that more than 6,000 construction projects are needed for industrial wastes, at a cost about equal to that for municipal facilities. On this basis, elimination of the backlog of needed industrial waste treatment plant construction, and provision of new facilities for rapidly expanding industry, will require expenditures averaging $575 to $600 million a year, if industry is to catch up by 1965.

Enforcement of pollution control laws.—While much yet needs to be learned about additional methods and procedures required for eliminating water pollution, the knowledge we already possess is not being fully utilized, and there is urgent need for the widespread application of existing engineering and scientific knowledge. As long as raw or inadequately treated sewage is being discharged into our rivers, we are not making full use of the resources and knowledge already available to us.

Widespread public understanding of this situation is, of course, required. In addition, however, there is need for adequate legal provisions for the enforcement of satisfactory pollution control measures. Although areas for improvement in the enforcement provisions of some State water pollution control laws exist, enforcement powers provided in most States are generally adequate. The principal need in the State water pollution control agencies is for adequate funding, staffing, and, above all, more use of the powers that are presently available to them after methods of persuasion have been demonstrated to be ineffective. The States need to keep up-to-date information on the quality of their waters. Finally, where dilatory or recalcitrant polluters are encountered, forceful and effective methods of enforcement must be used.

When State regulatory agencies are unable to resolve problems of interstate pollution, Federal enforcement procedures must be invoked. The Public Health Service, which is given authority for such action under the Federal Water Pollution Control Act, Public Law 660, 84th Congress, is maintaining continuing dockets on more than 125 interstate pollution problem areas. The States have requested the Public Health Service to institute proceedings in five of these areas and on the basis of studies, surveys and reports, the Service has initiated action in seven others.

Additional legislation.—Effective water pollution control programs must be supported by effective legislation tailored to meet specific problems and needs. As these problems and needs change, their supporting legislation should be reviewed and changed accordingly.

Water quality management can be achieved nationally only as the individual State, interstate and local agencies are able to administer effective programs, and as the Federal agencies are able to support these programs and carry out their Federal responsibilities. Many States have reasonably comprehensive water pollution control legislation but all need it. Such legislation should include provisions for adequate appropriations, for planning and programing water quality needs and uses, for workable enforcement procedures, for financing of remedial treatment facilities, and for issuing permits for new or modified sources of pollution.

Metropolitan areas are presenting serious water pollution problems. As the number and size of these residential, industrial complexes grow, the problems can be expected to become exceedingly difficult. Legislation is needed which will permit the various communities comprising the metropolitan region to work together effectively and equitably toward an integrated regional approach to common water and waste problems. One-fourth of present metropolitan centers cross State boundaries and legislation is needed to effect interstate cooperation and programing in water and waste problems in these areas.

There is a need for improvements in State laws governing the financing of waste treatment works, as well as for State assistance in such financing. Various improvements have, of course, been made through the years, and all States have incorporated many sound principles in their financing laws, including some unique provisions to satisfy particular demands of individual States. On the other hand, many of the State laws and practices appear rather restrictive with respect to debt limits and requirements for electoral approval, and many lack clear guidelines and controls. Although most States have liberalized and clari-

fied their public financing laws since the 1930's, none can be held up as a model. Improvements are still needed, including further simplification and liberalization to meet present conditions, which are substantially different from those of 20 years ago, particularly in the metropolitan areas. It may also be necessary for the Congress and States in general to consider legislation dealing with the financing of industrial waste treatment works, as some States have already done.

The need to manage water resources effectively and efficiently is also making it increasingly necessary to provide legislation for integrated river basin and regional water resource developments which would be participated in by all affected local, State and Federal interests. Such legislation should include mechanisms for resolving such major conflicts as that of who should pay the costs for these water resources projects, and who should benefit from them.

Public awareness and support.—Related to all the elements in water quality management is the need for a much better public understanding of the water pollution situation and greater public support for what needs to be done. Some segments of our population are ahead of the water planners in their thinking but too large a number lag far behind. Excellent support for water quality management has been given by the conservationists, municipal associations, women's organizations, fraternal and civic groups, some elements within industry, and by Members of the Congress. Overall, however, the general public has not been well informed.

Very important water resources decisions are being made and will continue to be made in the years ahead. If we are to have the force of public opinion behind water quality management, the facts must be presented to the public through well-thought-out programs using the most effective media, especially radio, television, and the popular press. With public support for water pollution control, it will be possible to meet the needs for adequate legislation and appropriations, and for planning, construction, and the other elements of a successful national water quality management program. Without public support the job ahead will be most difficult, if not impossible to accomplish. Past experiences have shown this clearly.

SUMMARY

1. Total withdrawals of fresh water for all purposes, in 1980, will almost equal total developable supplies, and may, by year 2000, amount to almost double the available water. In many river basins, water will have to be reused a number of times if future withdrawal demands are to be met.

2. Water in rivers and lakes is now being polluted by many kinds of substances, and this pollution will grow steadily worse unless effective pollution control can be achieved.

3. The increasing demands for water in the face of limited supplies and increasing pollution require that from now on water resources management be based on quality considerations as well as those of quantity.

4. Streams must continue to serve as residual waste carriers, for the foreseeable future, simply because there is nowhere else to dispose of waterborne wastes, but the increasing demands for water for all purposes including fish and wildlife and recreation, as well as municipal and industrial water supply, will require that wastes be engineered out of streams to the maximum extent possible.

5. Water quality management requires the preparation of comprehensive pollution control programs for each river basin or region, as a basis for determining the amount of water which can be made available for the various purposes to be served in the future. In a moderate-size river basin, such a program might take 3 to 4 years for its initial formulation, at a cost of from $1 to $3 million. It should be continuously revised thereafter as conditions warrant.

6. In the development of such programs, the application of basic economics is needed to develop valid yardsticks by which reliable dollar measurements can be made of the costs of water pollution and of the benefits from its control. With such data, water resources management can be accomplished on a sounder economic basis. Achievement of this goal will require measurements for the value of each water use. These may well differ according to the region or situation involved.

7. Successful management of water quality requires adequate information. This information should include data on sources, strengths, volumes, characteristics, and ultimate fate of wastes enter-

ing streams. Much additional information is also needed on the effects of the various substances and organisms contained in waste waters upon human and animal as well as plant life. Information is also needed on economical methods of removing or controlling them. Present programs for gathering information on water pollution, water quality, water consumption, and water treatment need to be greatly expanded.

8. Extensive expansion and intensification of research programs on the characteristics and effects of water pollution are required. In particular, much research effort should be devoted to the discovery of new and more effective methods of treating or removing the various pollutants from water. Other research on methods of detection, behavior, toxic and other effects, salvage value, and other aspects of water pollutants is also needed.

9. Construction of a backlog of almost 6,000 municipal sewage treatment plants is needed merely to catch up with existing sewage treatment needs. This will require an average annual expenditure of $600 million if these needs are to be met by 1965. Approximately the same number of industrial waste treatment plants are required to control existing pollution from this source, at an annual cost about equal to that for municipal treatment works. After 1965, continuing enlargement or replacement of existing plants and construction of additional new plants will be required to keep up with increasing waterborne waste disposal problems.

10. While much yet needs to be learned about additional methods of controlling water pollution, existing knowledge and methods are not being fully utilized, and raw or inadequately treated sewage and industrial wastes is still being discharged into streams and lakes. Effective methods of enforcing existing State water pollution control laws, and where these fail, the invoking of Federal enforcement procedures, is required to correct this situation. States have already requested the Public Health Service to institute proceedings in five cases, and the Service has initiated action in seven others.

11. Additional legislation tailored to meet specific situations and problems, is needed for effective water pollution control, as pollution problems increase. Water quality management can be achieved nationally only as individual State, interstate and local agencies are able to administer effective programs, and as Federal agencies are able to support these programs and carry out Federal responsibilities. Coordination of water supply and waste disposal activities in the growing number of complex metropolitan regions also requires special attention.

12. There is need for much better public understanding of the water pollution situation, together with greater public support for what needs to be done. This calls for well-thought-out programs to inform the public on these problems and needs, using the most effective media such as radio, television, and the popular press.

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